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DESCRIPTION

METHOD AND SYSTEM FOR DETECTING FAILURE OF RING NETWORK

TECHNICAL FIELD

This invention relates to method and system for detecting failure of a ring network in which a plurality of nodes are connected in loop by transmission lines, and paths are established in that transmission lines so as to conduct communications, and more particularly to method and system for detecting failure of a ring network configured such that a part where failure occurs can be automatically identified by making a double-loop connection of a plurality of nodes by a first transmission line and a second transmission line having mutually different transmission directions so that communications can be restored promptly when failure occurs.

BACKGROUND ART

Examples of commonly known communication systems which uses ring networks for conducting communications by loop-connecting a plurality of nodes by a transmission line and establishing paths in that transmission line include railroad management systems, sewer line management systems, airport management systems, river management systems and subway management systems.

In a railroad management system, a management center exists inside a management sector, and monitoring cameras and train sensors are arranged along the railroad tracks in that management sector. Information from those monitoring cameras and/or train sensors is collected at the management center. Train control information informing means such as signalers are also arranged along the railroad tracks.

Information on accidents and the like from neighboring management sectors is also collected in the management center. By using this information and information on this management sector, various decisions are made and, based on results of the decisions, such railroad management as controlling train operations and the like is effected using signalers and the like.

Conventional railroad management systems of this type are configured by devices and transmission lines such as are illustrated in Fig. 21. In this figure, 20-1 to 20-5 are nodes (hereinafter called remote stations) that function as management centers provided in each management sector, 21-1 to 21-p, 22-1 to 22-q, 23-1 to 23-r, 24-1 to 24-s, and 25-1 to 25-t are monitoring cameras or train sensors in the management sectors or local communication devices (hereinafter called terminals) serving as train control information detection means such as signalers and the like. 10 denotes a node (hereinafter called a central station) to which a node management unit 30 is connected and which controls the remote stations 20-1 to 20-5 and the terminals 21-1 to 25-t.

The central station 10 and remote stations 20-1 to 20-5 are connected in a loop by a transmission line 400 wherein optical cable, for example, is used, and configured such that the central station 10 transmits data to the first terminal and the remote stations 20-1 to 20-5 receive the data and transmit those data to the remote stations 20-1 to 20-5 downstream or to a central station 11. In a conventional system of this type, as may be understood from

the figure, a single-loop circuit configuration is common wherein data is transmitted in one direction with the central station 10 as the start and end points.

Today, however, development is rapidly progressing in efforts to devise a practical ATM (asynchronous transfer mode) switching method. By applying this ATM technology to such communication systems as described in the foregoing, it is now becoming possible to build flexible systems that exploit the advantages of ATM.

When the railroad management system described above is configured using ATM switching functions, it is possible to effect communication control such that information obtained by the terminals 21-1 to 25-t (such as train running condition video images produced by monitoring cameras or detection outputs from train sensors, etc.) is transmitted to the remote stations 20-1 to 20-5, the detection information noted above is transmitted by those remote stations 20-1 to 20-5 over a transmission line 400 to the downstream remote stations 20-1 to 20-5, and the detection information is also transmitted all the way to the central station 10 by sequentially performing that action at the remote stations 20-1 to 20-5. Further, the central station 10 obtains those pieces of detection information transmitted from the remote stations 20-1 to 20-5, processes them, and transmits control information to the remote stations 20-1 to 20-5 over the transmission line 400 again, and then the remote stations 20-1 to 20-5 provide the control information (such as, for example, information used for controlling the lighting of signalers, etc.) to the terminals 21-1 to 25-t.

Also, in a case where ATM switching is adopted, the information of the terminals 21-1 to 25-t (detection outputs from monitoring cameras and train sensors, signaler lighting control information, etc.) can be formed with the

same network of a transmission line 14, and one information content can be transmitted to a plurality of addresses by cell (cell: information) content.

In the operation management described above, when a system abnormality occurs, system operation becomes impossible. The reason for this is none other than that, as illustrated in Fig. 21, in a conventional system of this type, a single-loop circuit configuration is employed which transmits data in one direction with the central station 10 as the start point and as the end point.

That is, as based on this configuration, when, for example, a fault, line-break, or other failure occurs at one of the remote stations 20-1 to 20-5 or in the transmission line (optical cable) 400, not only can the central station 10 not acquire information of the remote stations 20-1 to 20-5 where the failure occurred or information of the terminals 21-1 to 25-t, but it cannot acquire any information at all, and system operation will come to a halt.

Furthermore, even in making repairs, it is not possible to detect the region the abnormality occurred in, whereupon it is necessary to examine the system sequentially from the start terminal to the end terminal, so that the time system functions are stopped becomes long. When such a situation as this develops in a railroad management system where safe operation is the highest priority, the unavoidable result is panic.

Thus, with a conventional system of this type, because a single-loop circuit configuration is adopted which transmits data in one direction with the central station as the start point and as the end point, when a failure occurs, for example, at the nth remote station or in the transmission line that connects the nth remote station and the (n-1)th remote station, information from the central station can be transmitted as far as the (n-1)th remote station, but

information of the various remote stations can then no longer be transmitted to the central station. As a result, the system functions have to be stopped.

After the system functions stop, moreover, it is necessary to identify the failed part and quickly make restorative repairs, but, in the conventional system configuration described in the foregoing, the failed part cannot be identified by the system itself, and maintenance personnel must conduct a search to find it, wherefore stopping the system functions for a prolonged time cannot be avoided.

The system functions must also be stopped when inspecting the remote stations or installing additional remote stations, wherefore flexibility is poor.

As a measure for dealing with this problem, the loop LAN having a double looped configuration has been known for some time, in almost all of which applications only the transmission line (optical cable) is doubled, and the physical portions are left in a single configuration, wherefore it is not possible therewith to flexibly cope with the detection and notification of failure information.

Also, since a dedicated line for loop switchover is required, this line cannot at all be shared with remote station branching/insertion switching functions.

DISCLOSURE OF THE INVENTION

That being so, an object of the present invention is to provide a failure detection method and system configured so that locations where failure occurs in a ring network wherein a plurality of nodes are loop-connected by a transmission line can be automatically identified, and configured so that communications can be swiftly restored when a failure occurs.

Another object of the present invention is to provide a communication system exhibiting high communication function reliability and capable of flexibly handling system modifications, wherein, when a failure occurs in a remote station or transmission line, communications can be maintained by recognizing that failed part and rebuilding a transmission line under the control of the central station, and restoration to the initial system configuration can be effected automatically and quickly after the failed part has been restored, and wherein the inspection and additional installation of remote stations can be handled using the functions described above, without stopping system functions.

In order to attain the objects stated above, the invention in claim 1 is a method of detecting failure of a ring network wherein communications are conducted by connecting a plurality of nodes in double loops consisting of a first transmission line and a second transmission line having mutually different transmission directions, and establishing paths on those transmission lines, characterized in that one of the nodes among the plurality of nodes is established as a central station and other nodes are established as remote stations; the central station transmits failure monitoring information to respective remote stations using the first transmission line; the remote stations, upon receiving the failure monitoring information through the first transmission line, loop back and return the received failure monitoring information to the central station using the second transmission line; and the central station identifies a failed part in the ring network based on whether or not the failure monitoring information looped back at each of the remote stations has been received correctly.

The invention in claim 2 is the invention in claim 1, characterized in that the first transmission line is used as a primary transmission line for

communications between the nodes, and the second transmission line is used as a secondary transmission line for communications between the nodes.

The invention in claim 3 is the invention in claim 1, characterized in that the nodes are arranged in a plurality of dispersed sites, and respectively accommodate one or a plurality of local communication terminals.

The invention in claim 4 is the invention in claim 1, characterized in that the nodes, respectively, have ATM switches, the failure monitoring information consists of fixed-length ATM cells, and the transmitting and returning of the failure monitoring information are performed by establishing paths through the ATM switches.

The invention in claim 5 is the invention in claim 1, characterized in that the failure monitoring information is transmitted periodically from the central station to the remote stations.

The invention in claim 6 is the invention in claim 1, characterized in that the central station transmits the failure monitoring information both using the first transmission line and using the second transmission line, and the remote stations, when the failure monitoring information has been received from the first transmission line, loop back and transmit that received failure monitoring information back to the central station using the second transmission line, and when that information has been received from the second transmission line, loop back and transmit that received failure monitoring information back to the central station using the first transmission line.

The invention in claim 7 is the invention in claim 1, characterized in that the remote stations transmit failure monitoring information to neighboring remote stations or to the central station using the first transmission line or the second transmission line, the neighboring remote

station or central station which has received that failure monitoring information loops back and transmits that failure monitoring information to a remote station, and the remote station which has received that failure monitoring information detects individual failures based on whether or not that failure monitoring information has been received correctly from the neighboring remote station or central station.

The invention in claim 8 is the invention in claim 1, characterized in that the central station, by identifying the failed part in the ring network, switches paths so as to bypass the identified failed part.

The invention in claim 9 is a method of detecting failure of a ring network wherein communications are conducted by connecting a plurality of nodes in double loops consisting of a first transmission line and a second transmission line having mutually different transmission directions, and establishing paths on those transmission lines, characterized in that one of the nodes among the plurality of nodes is established as a central station and other nodes are established as remote stations; the central station transmits failure monitoring information to respective remote stations using the first and second transmission lines; the remote stations, upon receiving the failure monitoring information through the first transmission line, loop back and return the received failure monitoring information to the central station using the second transmission line, and, upon receiving the failure monitoring information through the second transmission line, loop back and return the received failure monitoring information to the central station using the first transmission line; and the central station identifies a failed part in the ring network based on whether or not the failure monitoring information from each of the remote stations has been received correctly.

The invention in claim 10 is a method of detecting failure of a ring network wherein communications are conducted by connecting a plurality of nodes in double loops consisting of a first transmission line and a second transmission line having mutually different transmission directions, and establishing paths on those transmission lines, characterized in that the nodes transmit failure monitoring information to neighboring nodes using the first transmission line or the second transmission line; the neighboring nodes which have received the failure monitoring information loop back and return the failure monitoring information to the nodes that transmitted the failure monitoring information; and the nodes that have received the failure monitoring information detect individual failures based on whether or not the failure monitoring information has been received correctly from the neighboring nodes.

The invention in claim 11 is a system for detecting failure of a ring network wherein communications are conducted by connecting a plurality of nodes in double loops consisting of a first transmission line and a second transmission line having mutually different transmission directions, and establishing paths on those transmission lines, characterized in that one of the nodes among the plurality of nodes is established as a central station and other nodes are established as remote stations, the central station comprises failure monitoring information means for transmitting failure monitoring information to the remote stations, respectively, using the first transmission line; and failed part identification means for identifying failed parts in the ring network based on whether or not the failure monitoring information has been correctly received from the remote stations, and the remote stations comprise failure monitoring information return means for looping back and returning the received failure monitoring information to the central station using the second

transmission line when the failure monitoring information has been received by the first transmission line.

The invention in claim 12 is the invention in claim 11, characterized in that the first transmission line is used as the primary transmission line for communications between the nodes, and the second transmission line is used as a secondary transmission line for communications between the nodes.

The invention in claim 13 is the invention in claim 11, characterized in that the nodes are arranged in a plurality of dispersed sites, and respectively accommodate one or a plurality of local communication terminals.

The invention in claim 14 is the invention in claim 11, characterized in that the nodes, respectively, have ATM switches, the failure monitoring information consists of fixed-length ATM cells, and the transmitting and returning of the failure monitoring information are performed by establishing paths through the ATM switches.

The invention in claim 15 is the invention in claim 11, characterized in that the failure monitoring information means periodically transmit the failure monitoring information to the remote stations.

The invention in claim 16 is the invention in claim 11, characterized in that the failure monitoring information means transmit the failure monitoring information both using the first transmission line and using the second transmission line, and the failure monitoring information return means, when the failure monitoring information has been received from the first transmission line, loop back and transmit that received failure monitoring information back to the central station using the second transmission line, and when that information has been received from the second transmission line, loop back and transmit that received failure monitoring information back to the central station using the first transmission line.

The invention in claim 17 is the invention in claim 11, characterized in that the remote stations further comprise: individual failure monitoring information transmitting means for transmitting failure monitoring information individually to the central station or other remote stations neighboring those remote stations, using the first transmission line or the second transmission line; and failure detection means for detecting failures based on whether or not that failure monitoring information has been correctly received from the neighboring remote stations or central station; and in that the neighboring remote stations or central station further comprises individual failure monitoring information return means for transmitting that failure monitoring information so received back to the remote stations that transmitted that failure monitoring information.

The invention in claim 18 is the invention in claim 11, characterized in that the central station further comprises communication restoration means for restoring communications by performing automatic path switching so that failed parts in the ring network identified by the failed part identification means are bypassed.

The invention in claim 19 is a system for detecting failure of a ring network wherein communications are conducted by connecting a plurality of nodes in double loops consisting of a first transmission line and a second transmission line having mutually different transmission directions, and establishing paths on those transmission lines, characterized in that one of the nodes among the plurality of nodes is established as a central station and other nodes are established as remote stations, the central station comprises failure monitoring information transmitting means for transmitting failure monitoring information to the remote stations, respectively, using the first transmission line and the second transmission line; and failed part identification means for

identifying failed parts in the ring network based on whether or not the failure monitoring information has been correctly received from the remote stations, and the remote stations comprise failure monitoring information return means for looping back and returning the received failure monitoring information to the central station using the second transmission line when the failure monitoring information has been received from the first transmission line, and looping back and returning the received failure monitoring information to the central station using the first transmission line when that information has been received from the second transmission line.

The invention in claim 20 is a system for detecting failure of a ring network wherein communications are conducted by connecting a plurality of nodes in double loops consisting of a first transmission line and a second transmission line having mutually different transmission directions, and establishing paths on those transmission lines, characterized in that the nodes respectively comprise failure monitoring information transmitting means for transmitting failure monitoring information to neighboring other nodes using the first transmission line or the second transmission line; failure monitoring information return means for looping back and returning the received failure monitoring information to those other nodes, when the failure monitoring information has been received from the other nodes; and failure detection means for detecting failures based on whether or not that failure monitoring information has been correctly received from the neighboring other nodes.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a system configuration diagram in one embodiment of a communication system configured using a method and system for detecting failure of a ring network according to the present invention;

Fig. 2 is a block diagram illustrating the basic configuration of a central station in the communication system illustrated in Fig. 1;

Fig. 3 is a block diagram illustrating the basic configuration of a remote station in the communication system illustrated in Fig. 1;

Fig. 4 is a diagram illustrating the configuration of an ATM cell used in the communication system illustrated in Fig. 1;

Figs. 5(a) and 5(b) are diagrams of one example of a switching mode in an ATM switching unit corresponding to an input ATN cell;

Figs. 6(a) and 6(b) are diagrams of another example of a switching mode in an ATM switching unit corresponding to an input ATN cell;

Figs. 7(a) and 7(b) are diagrams of still another example of a switching mode in an ATM switching unit corresponding to an input ATN cell;

Figs. 8(a) and 8(b) are diagrams of yet another example of a switching mode in an ATM switching unit corresponding to an input ATN cell;

Fig. 9 is a schematic diagram of switch selection and cell transfer operations after switch selection in an ATM switching unit in a remote station receiving cells having the information content illustrated in the diagrams in Fig. 5 to 8 when those cells are mixed;

Fig. 10 is a flowchart of failure detection processing routines based on test cell transmission at the central station;

Fig. 11 is a flowchart of remote station processing routines in failure detection processing based on test cell transmission;

Fig. 12 is a diagram of how test cells are transmitted back in a specific example;

Fig. 13 is a diagram of how test cells are transmitted back in a specific example when a failure has occurred;

Fig. 14 is a flowchart of central station processing routines for detecting sites where failures have occurred which combine processing for transmitting test cells from the central station via the primary transmission line and processing for transmitting test cells via a secondary transmission line;

Fig. 15 is a flowchart of other central station processing routines for detecting sites where failures have occurred which combine processing for transmitting test cells from the central station via the primary transmission line and processing for transmitting test cells via a secondary transmission line;

Fig. 16 is a diagram for describing system reconstruction, in a specific example, after a failure has occurred, by the central station;

Fig. 17 is a diagram illustrating another embodiment relating to failure occurrence monitoring and system reconstruction after a failure has occurred;

Fig. 18 is a system configuration diagram in another embodiment of a communication system configured using method and system for detecting failure of a ring network according to the present invention;

Fig. 19 is a diagram of how a node monitors the communication routes with the nodes connected to both ends thereof using communication route monitoring cells;

Fig. 20 is a diagram of how, when a failure occurs in a communication route of a node, that failure is detected by the nodes connected to both ends thereof; and

Fig. 21 is a diagram illustrating the configuration of a conventional communication system.

BEST MODE FOR CARRYING OUT THE INVENTION

A detailed description is now given of one embodiment of the present invention making reference to the attached drawings.

Fig. 1 is a system configuration diagram in one example of a communication system configured using method and system for detecting failure of a ring network according to the present invention.

In Fig. 1, the communication system is configured by connecting a plurality of nodes (nodes 20-1 to 20-5) each accommodating one or a plurality of local communication devices (terminals 21-1 to 25-t) by looped transmission lines (transmission lines 40 and 50) originating at a center device (node 10). This communication system is an example which is applicable to a railroad management system, and particularly shows a system configuration example wherein ATM switches are used in the above-described node 10 and nodes 20-1 to 20-5.

In Fig. 1, in terms of the device-related configuration, there are provided a node 10 (central station), which a node management unit 30 is connected to, for performing information processing for the system and overall system operation management, a plurality of nodes (remote stations) 20-1 to 20-5 arranged in a plurality of dispersed sites, and one or a plurality of terminals 21-1 to 25-t connected to each of those remote stations 20-1 to 20-5.

Of these, the central station 10 and remote stations 20-1 to 20-5, as described in the foregoing, employ ATM switching equipment, and, as will be described in detail below, each have a built-in ATM switch.

In terms of the communication route-related configuration, there are provided a primary transmission line 40 connected so that data can be transferred clockwise, and a secondary transmission line 50 for transferring data in the opposite direction (counterclockwise) to that of the primary transmission line 40, both starting and ending at the central station 10. These

transmission lines 40 and 50 are configured by optical cables, for example, with each configuring a loop network connecting the remote stations 20-1 to 20-5. 71-1, 71-2, 71-3, 71-4, and 71-5 are transmission lines that respectively connect the remote stations 20-1 to 20-5 with the terminals 21-1 to 25-t, while 72 is a transmission line that connects the central station 10 and the node management unit 30.

As described above, the transmission lines in the communication system in this embodiment are doubled with at least two transmission lines, namely a primary transmission line and a secondary transmission line, the transmission directions whereof must be opposite directions (where, for example, if the transmission direction of the primary transmission line is: central station → 1st remote station → 2nd remote station → ··· → nth remote station → central station, then the transmission direction of the secondary transmission line is: central station → nth remote station → ··· 2nd remote station → 1st remote station → central station), configured such that the start terminals and end terminals of both transmission lines are connected to the central station 10. The central station 10 and the remote stations 20-1 to 20-5 are also equipped with transmitters, receivers, and physical layer end terminal devices having LOS/LOF (loss of signal = signal break, loss of frame = frame out of synchronization) detection functions.

The remote stations 20-1 to 20-5 are equipped with ATM switches that take cells from the terminals 21-1 to 25-t and ATM cells from the central station 10 or the upstream remote stations 20-1 to 20-5, mix them, and transmit them to the downstream central station 10 or remote stations 20-1 to 20-5 over the primary transmission line 40, or transmit them over the secondary transmission line to the upstream central station or remote stations 20-1 to 20-5.

Controlling the switching of these ATM switches is done, as will be described further below, on the basis of control information in the ATM cells transmitted from the central station 10. By the switching control of these ATM switches, functions will be provided to the remote stations 20-1 to 20-5 for connecting with the primary transmission line 40 and the secondary transmission line 50 as necessary to form individual small loops between the central station 10.

The central station 10 transmits a failure monitoring cell which contains a failure monitoring command at fixed time intervals to the primary transmission line 40. The remote stations 20-1 to 20-5, in response to that failure monitoring cell, form the small loops noted above and transmit a reply cell to the secondary transmission line 50. By doing that, the central station 10 can itself detect either that there is no failure by the fact that a reply cell for the failure monitoring cell was received from the secondary transmission line 50, or that a failure has occurred in the remote stations 20-1 to 20-5 or transmission line sector by the fact that no reply cell was received from the secondary transmission line 50.

The central station 10, furthermore, upon recognizing a failed part, issues control information loaded with turn-back information, addressed to the remote stations 20-1 to 20-5 neighboring the failed part. These addressed remote stations 20-1 to 20-5, when the information contained in the control information addressed to themselves is turn-back information, form the small loops noted above, and thereafter either transmit the cells received from the primary transmission line 40 to the secondary transmission line 50, or transmit the cells received from the secondary transmission line 50 to the primary transmission line 40. In this system, therefore, even when a failure has occurred, a function is effected whereby communication functions are

restored by looping back information before and after the site of failure occurrence.

Incidentally, to perform the control for restoring these communication functions, in addition to the control from the central station 10, direct control from the node management unit 30 connected to this central station 10 may also be effected.

Fig. 2 is a block diagram illustrating the basic configuration of the central station 10 in the communication system illustrated in Fig. 1.

In Fig. 2, the central station 10 is configured by comprising a transmission line interface 101, a transmission line interface 102, an ATM switching unit 103, a terminal interface unit 104, and a controller 105.

Here, the transmission line interface 101 is connected to the primary transmission line 40 from upstream and to the secondary transmission line 50 going downstream, and is configured by comprising a receiving unit 101a for receiving ATM cells transmitted by the primary transmission line 40 from upstream and a transmitting unit 101b for transmitting ATM cells to the secondary transmission line 50 going upstream, and connects ATM cells transmitted and received via the primary transmission line 40 from upstream and the secondary transmission line 50 going upstream to the ATM switching unit 103. This transmission line interface 101 also has the LOS/LOF detection functions described earlier.

Also, the transmission line interface 102 is connected to the primary transmission line 40 going downstream and to the secondary transmission line 50 from downstream, and is configured by comprising a receiving unit 102a for receiving ATM cells transmitted by the secondary transmission line 50 from downstream and a transmitting unit 102b for transmitting ATM cells to the primary transmission line 40 going downstream, and connects ATM cells

transmitted and received via the primary transmission line 40 going downstream and the secondary transmission line 50 from downstream to the ATM switching unit 103. This transmission line interface 102 also has the LOS/LOF detection functions described earlier.

The terminal interface unit 104 is connected via the transmission line 72 to the node management unit 30, and connects signals transmitted and received to and from the node management unit 30 as ATM cells to the ATM switching unit 103.

The ATM switching unit 103 performs the switching connection of ATM cells transmitted and received via the transmission line interface 101, ATM cells transmitted and received via the transmission line interface 102, and ATM cells transmitted and received via the terminal interface unit 104.

More specifically, the ATM switching unit 103 determines where to output ATM cells that are input, according to address information contained in the header portion of the ATM cell, that is, according to address information VPI/VCI comprising a VPI (virtual path identifier) and a VCI (virtual channel identifier), and performs ATM cell switching connections so that the ATM cells are output to the output destination so determined.

If the VPI/VCI of a cell to be extracted by the central station 10 is established beforehand, this cell can be fetched into the controller 105 of the central station 10 when it is input.

The ATM switching unit 103, moreover, is so configured that input cells are scheduled according to prescribed priorities and output to the transmission line interfaces 101 and 102. Further, it is so configured that any cell can be inserted at the central station 10.

The controller 105, which is connected to the ATM switching unit 103 also processes fetched cells and controls the switching connections of the

ATM cell in the ATM switching unit 103, in addition to perform general control on the overall operation of the central station 10,.

Fig. 3 is a block diagram illustrating the basic configuration of the remote station 20-1 illustrated in Fig. 1.

In Fig. 3, the remote station 20-1 is configured by comprising a transmission line interface 201, a transmission line interface 202, an ATM switching unit 203, a terminal interface 204, and a controller 205.

Here, the transmission line interface 201 is connected to the primary transmission line 40 from upstream and to the secondary transmission line 50 going downstream, and is configured by comprising a receiving unit 201a for receiving ATM cells transmitted by the primary transmission line 40 from upstream and a transmitting unit 201b for transmitting ATM cells to the secondary transmission line 50 going upstream, and connects ATM cells transmitted and received via the primary transmission line 40 from upstream and the secondary transmission line 50 going upstream to the ATM switching unit 203. The transmission line interface 201 also has the LOS/LOF detection functions described earlier.

Also, the transmission line interface 202 is connected to the primary transmission line 40 going downstream and to the secondary transmission line 50 from downstream, and is configured by comprising a receiving unit 202a for receiving ATM cells transmitted by the secondary transmission line 50 from downstream and a transmitting unit 202b for transmitting ATM cells to the primary transmission line 40 going downstream, and connects ATM cells transmitted and received via the primary transmission line 40 going downstream and the secondary transmission line 50 from downstream to the ATM switching unit 203. The transmission line interface 202 also has the LOS/LOF detection functions described earlier.

The terminal interface unit 204 is connected via the transmission line 71-1 to the terminals 21-1 to 21-p, and connects signals transmitted and received to and from the terminals 21-1 to 21-p as ATM cells to the ATM switching unit 203.

The ATM switching unit 203 performs the switching connection of ATM cells transmitted and received via the transmission line interface 201, ATM cells transmitted and received via the transmission line interface 202, and ATM cells transmitted and received via the terminal interface unit 204.

Here, the ATM switching unit 203, in the same manner as the ATM switching unit 103, determines where to output ATM cells that are input according to address information VPI/VCI contained in the header portion of the ATM cell, and performs the switching connections of the ATM cells so that the ATM cells are output to the determined destination.

Here, if the VPI/VCI of a cell extracted by the remote station 20-1 is established beforehand, the cell can be fetched to the controller 205 of the remote station 20-1 when that cell is input,.

In the ATM switching unit 203, moreover, the configuration is such that input cells are scheduled according to prescribed priorities and output to the transmission line interfaces 201 and 202, and the configuration is also such that any cell can be inserted at the remote station 20-1.

The controller 205, which is connected to the ATM switching unit 203, in addition to generally controlling the overall operation of the remote station 20-1, also processes fetched cells and controls the ATM cell switching connections in the ATM switching unit 203.

In Fig. 3, the configuration of the remote station 20-1 is illustrated, and the other remote stations 20-2 to 20-5 are configured in the same manner as the remote station 20-1 illustrated in Fig. 3.

Next, the operations of the communication system are described in order. In a railroad management system, for example, for the terminals 21-1 to 25-t indicated in Fig. 1, monitoring cameras, train sensors, or signalers or the like are arranged along the railroad track, and various types of information relating to the running situation are detected by these terminals. The detection information from these terminals 21-1 to 25-t is collected at the remote stations 20-1 to 20-5 through the transmission lines 71-1 to 71-5. Thus the remote stations 20-1 to 20-5 are distributed among a plurality of locations, and data collection for a plurality of regions is performed respectively.

The data collected in the remote stations 20-1 to 20-5 in the various dispersed regions are gathered in the central station 10 as monitoring data for each region through the primary transmission line 40, by way of each of the downstream remote stations 20-1 to 20-5 successively. The central station 10 judges how the trains are running by referencing the information collected from those remote stations 20-1 to 20-5, and informs the remote stations 20-1 to 20-5 of the accident information and train congestion information for the neighboring management sectors for each via the primary transmission line 40.

In response thereto, remote stations 20-1 to 20-5 that have obtained their own management sector information or neighboring sector information from the central station 10 transfer information, such as information concerning signal lighting controls and the like for stopping trains corresponding to the received information, to their terminals 21-1 to 25-t, such as signalers, etc., under their own control.

The central station 10, furthermore, in the same manner as when communicating the control information described in the foregoing, transmits failure monitoring test cells to the remote stations 20-1 to 20-5, either

continually or at certain intervals, to monitor whether or not there are any anomalies in the remote stations 20-1 to 20-5 or in the transmission lines 40 and 50. Normally, information is collected via the primary transmission line 40, and the secondary transmission line 50 is ordinarily used as an emergency monitoring line by each of the remote stations 20-1 to 20-5 for transmitting their own monitoring information (replay results to the test cells) to the central station 10.

Information is transmitted by the method of transmitting cells from the central station 10 over the primary transmission line 40. The cells can be loaded with information having different content. Thus, in terms of the categories of cells transmitted from the central station 10, there will be cells processed by the remote stations 20-1 to 20-5 and transmitted to the terminals 21-1 to 25-t, cells transmitted to the downstream remote stations 20-1 to 20-5, and test cells that are to be transmitted back to the central station 10.

These cells are distinguished, and their destinations determined, by the remote stations receiving them, according to the VPI and VCI address information inside the cells. Here, the configuration of a cell containing mostly address information is illustrated in Fig. 4. The cell 60 is formed by a 48-byte digital information portion 61 and a 5-byte header portion 62.

Information to be transmitted from the central station 10 (i.e. user data and the like) is contained in the digital information portion 61, while control information, that is, address information, is contained in the header portion 62.

The VPI (virtual path identifier) and VCI (virtual channel identifier) described earlier are contained in the address information, and it is by these pieces of address information that the addresses and information content are distinguished.

In the case of this system, the VPI is the address station number for the remote stations 20-1 to 20-5, while the VCI indicates information content. Here, if we define the values of VCI such that "10" is the content of a failure monitoring test cell, "20" the content of a congestion information cell, and "30" the content of an accident information cell (the address information for these being defined when operating the system), then, if VPI = 1 and VCI = 30, for example, then that cell is accident information for the remote station 20-1 connected first as seen from the central station 10, whereas if VPI = n and VCI = 10, then that cell is a failure monitoring test cell for the nth remote station 20-n as seen from the central station 10.

As described in the foregoing, in view of the fact that the remote stations 20-1 to 20-5 can always identify the content of received information, by transmitting the prescribed cells from the central station 10 via the transmission line 40 or 50 to the remote stations 20-1 to 20-5, by causing the remote stations 20-1 to 20-5 at the destinations to perform switching control corresponding to the results of distinguishing those cells, and by collecting the circulating cells that have been subjected to that switching control in the central station 10 and analyzing them, the central station 10 itself can perform system operation management such as failure detection by, system reconstruction after the occurrence of a failure, or restoration of the system to the initial state after failure recovery.

The switching control operation in the remote stations 20-1 to 20-5 described above is now explained citing specific examples. In Fig. 5 to 8 are illustrated the content of a cell 60 transmitted from the central station 10 and various switching modes for the ATM switching units 203 in the remote stations 20-1 to 20-5 based on that cell 60. The remote station indicated in these diagrams is in every case the remote station 20-n which is the nth

remote station as seen from the central station 10, which is built into a communication system configuration such as is illustrated in Fig. 1 by the primary transmission line 40 indicated by solid lines and the secondary transmission line 50 indicated by broken lines.

In Fig. 5(a), the cell 60 represents congestion information for the remote station 20-n which is the nth remote station as seen from the central station 10, in the header portion 62 whereof VPI is set to n and VCI to 20. When this cell is received, the ATM switching unit 203 in the remote station 20-n, as illustrated in Fig. 5(b), is switched so that the primary transmission line 40 used for receiving that cell 60 is connected to the transmission line 71 toward the terminal accommodated in that remote station 20-n.

In Fig. 6(a), the cell 60 represents congestion information for the remote station 20-(n + 1) that is the (n + 1)th remote station as seen from the central station 10, in the header portion 62 whereof VPI is set to n + 1 and VCI to 20. When the cell 60 is received, the ATM switching unit 203 in the remote station 20-n is switched so that the primary transmission line 40 used for receiving that cell 60 is as the primary transmission line 40 to the remote station 20-(n + 1) downstream from that remote station 20-n.

In Fig. 7, the cell 60 represents accident information for the remote station 12 that is the (n + 2)th remote station as seen from the central station 10, in the header portion 62 whereof VPI is set to n + 2 and VCI to 30. When the cell 60 is received, the ATM switching unit 203 in the remote station 20-n, as in the mode illustrated in Fig. 6(b), and as illustrated in Fig. 7(b), switches the primary transmission line 40 used for receiving that cell 60 as the primary transmission line 40 to the remote station 20-(n + 1) downstream from that remote station 20-n.

In Fig. 8, the cell 60 is a failure monitoring test cell for the remote station 12 that is the nth remote station as seen from the central station 11, in the header portion 62 whereof VPI is set to n and VCI to 10. When the cell 60 is received, the ATM switching unit 203 in the remote station 20-n, as illustrated in Fig. 8(b), is switched so that the primary transmission line 40 used for receiving that cell 60 is connected to the secondary transmission line 50.

Fig. 9 is a schematic diagram illustrating the switch selection of cell 60 when the cells 60 having the information content illustrated in each of the diagrams of Figs. 5 to 8 exit at the ATM switching unit 203 in the remote station 20-n that receives the cells 60, and the transfer operations of cell 60 after the switch selection.

The case considered here is one wherein the cells 60 (cell A, cell B, cell C and cell D) are transmitted via the primary transmission line 14 to the nth remote station 20-n from either the central station 10 or an upstream remote station. Under such conditions as these, first, the nth remote station 20-n which receives cell A (VPI = n, VCI = 20) recognizes that the information content of the cell A is congestion information to the nth remote station 12, and the ATM switching unit 203 in that remote station performs switching as illustrated in Fig. 5(b) so that the received cell A can be information-processed in that remote station 20-n and transmitted to a terminal accommodated in that that remote station 20-n. By doing so, the cell A is transmitted to the transmission line 71 to the terminal accommodated in that remote station 20-n via the ATM switching unit 203 in that remote station 20-n.

Next, in the nth remote station 20-n that received cell B (VPI = n + 1, VCI = 20), in response to the results of recognizing that the information

content of that cell B is congestion information to the (n + 1)th remote station 12, the ATM switching unit 203 in that remote station is switched to a mode like that illustrated in Fig. 6(b) so that it is possible for that cell B to be transmitted to the (n + 1)th remote station 12. By doing so, the cell B is transmitted to the primary transmission line 40 on the downstream side via the ATM switching unit 203 in that remote station 20-n.

Following thereupon, in the nth remote station 20-n that received the cell C (VPI = n + 2, VCI = 30), in response to the results of recognizing that the information content of that cell C is accident information to the (n + 2)th remote station 12, the ATM switching unit 203 in that remote station is switched to a mode like that illustrated in Fig. 7(b) so that it is possible for that cell C to be transmitted to the (n + 2)th remote station 20-(n + 2). By doing so, the cell C is transmitted to the primary transmission line 40 on the downstream side via the ATM switching unit 203 in that remote station 20-n.

Further, in the nth remote station 20-n that received the cell D (VPI = n, VCI = 10), in response to the results of recognizing that the information content of that cell D is a failure monitoring test cell to the nth remote station 20-n (that station), the ATM switching unit 203 in that remote station is switched to a mode like that illustrated in Fig. 8(b) so that it is possible for that cell D to be transmitted to the (n - 1)th remote station 20-(n - 1). In this switching condition, the cell D is looped back in the nth remote station 20-n from the primary transmission line 40 to the secondary transmission line 50, and is transmitted all the way to the central station 10 through the (n – 1)th, (n – 2)th, ..., 2nd, and 1st remote stations.

As described in the foregoing, as a result of the remote stations 20-1 to 20-5 themselves switching their own ATM switches according to the cell information content, as illustrated in Fig. 9, cell A is transmitted as cell A' to

the terminal, cells B and C, respectively, are transmitted as cells B' and C' to the downstream remote station 20-(n + 1), and cell D is transmitted as cell D' to the central station 10 or to an upstream remote station.

In conjunction with such cell transmission control, the central station 10 monitors the test cells transmitted back from the remote stations 20-1 to 20-5. Thus, at the central station 10, when test cells are transmitted back, judgments can be made that no abnormality has occurred either in the transmission lines between the transmitting remote stations 20-1 to 20-5 or in the remote stations 20-1 to 20-5, whereas, when test cells are not transmitted back, it can be judged either that an abnormality has developed in the remote stations 20-1 to 20-5 (there being a remote station 20-1 to 20-5 that did not transmit, therefore determining which of those remote stations 20-1 to 20-5 it was), or that an abnormality has developed in a transmission line.

Here, as to the criteria for determining whether or not test cells have been transmitted back at the central station 10, the times from the transmissions of the test cells until those test cells are transmitted back via the remote stations 20-1 to 20-5 are defined, so that, for example, with respect to some remote station 20-1 to 20-5, if a cell is not transmitted back within 2 to 3 minutes, for example, that constitutes a time-over, whereupon it is judged that a failure has occurred, and with respect to another remote station 20-1 to 20-5, if a cell is not transmitted back within 4 to 5 minutes, for example, that constitutes a time-over, whereupon it is judged that a failure has occurred.

In such cases, needless to say, the judgment time for remote stations 20-1 to 20-5 on the upstream side, as seen from the central station 10, and the judgment time for remote stations 20-1 to 20-5 on the downstream side can be established at different values.

Fig. 10 is a flowchart of failure detection processing routines based on test cell transmission at the central station 10.

In Fig. 10, the failure detection processing based on the test cell transmission is performed regularly at prescribed preset times.

When the failure detection processing based on the test cell transmission is started, first, a number n which indicates the order number of a remote station as seen from the central station 10 transmitting the test cell is set to 1 (step 111), and the test cell is transmitted to the nth remote station as seen from the central station 10 via the primary transmission line 40 (step 112).

Next, a check is made to determine whether the test cell transmitted to that nth remote station has been looped back at that nth remote station and received normally by the central station 10 via the secondary transmission line 50 (step 113).

Here, if it is judged that the test cell has been received normally via the secondary transmission line (YES in step 113), then the number n indicating the order number of the remote station as seen from the central station 10 is incremented by "1" (step 114), and, next, a check is made to determine whether the number n indicating the order number of the remote station as seen from the central station 10 has reached the number N which is the total number of remote stations in the communication system (step 115).

If it is judged by the judgment in that step 115 that the number n indicating the order number of the remote stations as seen from the central station 10 has not reached N, i.e. the total number of remote stations in the communication system (NO in step 115), then step 112 is returned to, and the routines in steps 112 to 115 are repeated.

If it is judged by the judgment in that step 115 that the number n indicating the order number of the remote stations as seen from the central station 10 has reached N, i.e. the total number of remote stations in the communication system (YES in step 115), that means, in this case, that the test cells from all of the remote stations in this communication system have been looped back from the primary transmission line 40 to the secondary transmission line 50 and received by the central station 10, wherefore it is judged that there are no failures affecting any of the remote stations in the communication system (step 116), and the failure detection processing based on the test cell transmission is terminated.

However, in the judgment in step 113, if it is judged that the test cell transmitted to the nth remote station could not be looped back by the nth remote station and received normally by the central station 10 (NO in step 113), then it is judged that a failure has occurred which affects the nth remote station as seen from the central station 10 (step 117).

Fig. 11 is a flowchart of remote station processing routines in failure detection processing based on the test cell transmission described above.

In Fig. 11, processing routines in the nth remote station as seen from the central station 10 are described.

In Fig. 11, when this remote station receives a cell from the central station 10 via the primary transmission line 40 (step 211), a check is first made to determine that the VPI in this received cell is addressed to that station, that is, that VPI = n (step 212). If it is judged here that that received cell is addressed to that station, that is, that VPI = n (YES in step 212), then a check is made next to determine whether the VCI in that received cell indicates a test cell, that is, whether VCI = 10 (step 213).

If it is judged here that that received cell indicates a test cell, that is, that VCI = 10 (YES in step 213), then, at the remote station, turn-back processing is performed to loop back the test cell transmitted from the central station 10 via the secondary transmission line 50 (step 214), and the processing at the remote station is terminated.

However, if it is judged in step 212 that the cell received from the primary transmission line 40 is not addressed to that station, that is, that VPI ≠ n (NO in step 212), then processing is performed to transmit the received cell to the next remote station via the primary transmission line 40 (step 216).

Also, if it is judged in step 213 that the cell received from the primary transmission line 40 is not a test cell, that is, that VCI ≠ 10 (NO in step 213), then, in this remote station, cell receiving processing is performed to fetch that received cell (step 215).

A specific example of the test cell return mode described in the foregoing is illustrated in Fig. 12. In the case illustrated here, a test cell addressed to the remote station 20-(n – 1) is transmitted from the central station 10 via the primary transmission line 40, and this test cell is looped back at the remote station 20-(n – 1) and received normally by the central station 10 via the secondary transmission line 50. In this case, it is judged that no failure has occurred as far as the remote station 20-(n – 1), in the direction of the primary transmission line 40, or in the primary transmission line 40 and secondary transmission line 50 therebetween.

In Fig. 13 is illustrated a situation wherein a test cell addressed to remote station 20-n was transmitted from the central station 10 via the primary transmission line 40, after the test cell transmission processing illustrated in Fig. 12 was performed, but the test cell that should have been looped back at the remote station 20-n could not be received from the

secondary transmission line 50 by the central station 10. In this case, it can be judged at the central station 10 that a failure has occurred either at the remote station 20-n or in the transmission line 40 or 50 between the remote station 20-(n – 1) and the remote station 20-n.

In this case, furthermore, a failure in a remote station or the transmission line 40 or 50 between the remote station 20-n and the central station 10 cannot be detected.

Thereupon, it is possible to combine the processing for transmitting test cells via the primary transmission line 40 and the processing for transmitting test cells via the secondary transmission line 50 and thus configure the system so that the site of failure occurrence can be identified more accurately.

Fig. 14 is a flowchart of central station 10 processing routines for detecting sites where failures have occurred which combine processing for transmitting test cells from the central station 10 via the primary transmission line 40 and processing for transmitting test cells via a secondary transmission line 50.

In the processing routines illustrated in Fig. 14, first, a test cell is transmitted from the central station 10 via the primary transmission line 40, and, when a failure is detected by this routine, next a test cell is transmitted via the secondary transmission line 50 to detect the failure.

More specifically, in Fig. 14, first, the number n indicating the order number of the remote station as seen from the central station 10 transmitting the test cell is set to 1 (step 121), and a test cell is transmitted via the primary transmission line 40 to that nth remote station as seen from the central station 10 (step 122).

Next, a check is made to determine whether the test cell transmitted to that nth remote station has been looped back at that nth remote station and

received normally via the secondary transmission line 50 by the central station 10 (step 123).

If it is judged here that the test cell has been received normally via the secondary transmission line (YES in step 123), then the number n indicating the order number of the remote stations as seen from the central station 10 is incremented by "1□ (step 124), and a check is made next to determine whether or not the number n indicating the order number of the remote stations as seen from the central station 10 has reached N, i.e. the total number of remote stations in this communication system (step 125).

If it is judged by the judgment in that step 125 that the number n indicating the order number of the remote stations as seen from the central station 10 has not reached N, i.e. the total number of remote stations in the communication system (NO in step 125), then step 122 is returned to, and the routines in steps 122 to 125 are repeated.

If it is judged by the judgment in that step 125 that the number n indicating the order number of the remote stations as seen from the central station 10 has reached N, i.e. the total number of remote stations in the communication system (YES in step 125), that means, in this case, that the test cells from all of the remote stations in this communication system have been looped by from the primary transmission line 40 to the secondary transmission line 50 and received by the central station 10, wherefore it is judged that there are no failures affecting any of the remote stations in the communication system (step 126), and the failure detection processing based on the test cell transmission is terminated.

However, in the judgment in step 123, if it is judged that the test cell transmitted to the nth remote station could not be looped back by the nth remote station and received normally by the central station 10 (NO in step

123), then a failure has occurred which affects the nth remote station as seen from the central station 10, wherefore a number m indicating the order number of the remote stations as seen from the central station 10 which transmitted the test cell is set to N, i.e. the total number of remote stations in this communication system (step 127), and a test cell is transmitted via the secondary transmission line 50 to the mth remote station as seen from the central station 10 (step 128).

Next, a check is made to determine whether or not the test cell transmitted to that mth remote station has been looped back at the mth remote station and received normally via the primary transmission line 40 by the central station 10 (step 129).

If it is here judged that the test cell has been received normally via the primary transmission line (YES in step 129), then the number m indicating the order number of the remote station as seen from the central station 10 is decremented by "1" (step 130), and a check is next made to determine whether or not the number m indicating the order number of the remote stations as seen from the central station 10 has reached n + 1 (step 131).

If by the judgment in the step 131 it is judged that the number m indicating the order number of the remote stations as seen from the central station 10 has not reached n + 1 (NO in step 131), then step 128 is returned to, and the routines in steps 128 to 131 are repeated.

If by the judgment in step 131 it is judged that the number m indicating the order number of the remote stations as seen from the central station 10 has reached n + 1 (YES in step 131), that means that test cells from the remote stations up to the (n + 1)th remote station from the central station 10 in this communication system, in the direction of the secondary transmission line 50, have been normally looped back from the secondary transmission line 50 to

the secondary transmission line 40 and received by the central station 10, wherefore it is judged that there are no failures affecting the remote stations to the (n + 1)th remote station from the central station 10 in this communication system, in the direction of the secondary transmission line 50, that is, that no failures have occurred that affect the nth remote station (step 132).

If, however, it is judged in step 129 that the test cell could not be normally received via the primary transmission line (NO in step 129), then it is judged that a failure has occurred between the nth remote station and the mth remote station (step 133).

Fig. 15 is a flowchart of other central station 10 processing routines for detecting sites where failures have occurred which combine processing for transmitting test cells from the central station 10 via the primary transmission line 50 and processing for transmitting test cells via the secondary transmission line 40.

In the processing routines illustrated in Fig. 15, first, failure detection is performed, transmitting a test cell from the central station 10 via the primary transmission line 40 and, concurrently therewith, transmitting a test cell via the secondary transmission line 50. Based on such a configuration as this, failure detection processing is performed in parallel in both directions, that is, in the direction of the primary transmission line 40 and in the direction of the secondary transmission line 50, wherefore failed part identification processing can be performed quickly.

More specifically, in Fig. 15, first, the number n indicating the order number of the remote stations as seen from the central station 10 transmitting the test cell is set to 1 (step 141), and the number m indicating the order number of the remote stations as seen from the central station 10 is set to N,

i.e. to the total number of remote stations in this communication system (step 147).

Failure detection processing is then conducted in parallel in both directions, that is, in the direction of the primary transmission line 40 and in the direction of the secondary transmission line 50.

More specifically, in the failure detection processing done in the primary transmission line 40 direction, a test cell is first transmitted via the primary transmission line 40 to the nth remote station as seen from the central station 10 (step 142).

Next, a check is made to determine whether the test cell transmitted to that nth remote station was able to be looped by at that nth remote station and received normally via the secondary transmission line 50 by the central station 10 (step 143).

If it is here judged that the test cell was able to be normally received via the secondary transmission line (YES in step 143), the number n indicating the order number of the remote stations as seen from the central station 10 is incremented by "1" (step 144), and a check is next made to determine whether the number n indicating the order number of the remote stations as seen from the central station 10 is equal to the number m indicating the order number of the remote stations as seen from the central station 10 in the failure detection processing in the direction of the secondary transmission line 50 processed in parallel (step 145).

If by the judgment in the step 145 it is judged that the number n indicating the order number of the remote stations as seen from the central station 10 is not equal to the number m indicating the order number of the remote stations as seen from the central station 10 in the failure detection processing in the direction of the secondary transmission line 50 processed in

parallel (NO in step 145), then step 142 is returned to, and the routines in steps 142 to 145 are repeated.

If by the judgment in step 145 it is judged that the number n indicating the order number of the remote stations as seen from the central station 10 is now equal to the number m indicating the order number of the remote stations as seen from the central station 10 in the failure detection processing in the direction of the secondary transmission line 50 processed in parallel (YES in step 145), that means that the test cells from all of the remote stations in this communication system were able to be received normally from the secondary transmission line 50 or the primary transmission line 40, wherefore it is judged that there are no failures affecting any of the remote stations in this communication system (step 146), and the failure detection processing based on the test cell transmission is terminated.

More specifically, in the failure detection processing done in the secondary transmission line 50 direction, a test cell is first transmitted via the secondary transmission line 50 to the mth remote station as seen from the central station 10 (step 148).

Next, a check is made to determine whether the test cell transmitted to that mth remote station was able to be looped back at that mth remote station and received normally via the primary transmission line 40 by the central station 10 (step 149).

If it is here judged that the test cell was able to be normally received via the primary transmission line 40 (YES in step 149), the number m indicating the order number of the remote stations as seen from the central station 10 is decremented by "1" (step 150), and a check is next made to determine whether the number m indicating the order number of the remote stations as seen from the central station 10 is equal to the number n indicating the order

number of the remote stations as seen from the central station 10 in the failure detection processing in the direction of the primary transmission line 40 processed in parallel (step 151).

If by the judgment in the step 151 it is judged that the number m indicating the order number of the remote stations as seen from the central station 10 is not equal to the number n indicating the order number of the remote stations as seen from the central station 10 in the failure detection processing in the direction of the primary transmission line 40 processed in parallel (NO in step 151), then step 148 is returned to, and the routines in steps 148 to 151 are repeated.

If by the judgment in step 151 it is judged that the number m indicating the order number of the remote stations as seen from the central station 10 is now equal to the number n indicating the order number of the remote stations as seen from the central station 10 in the failure detection processing in the direction of the primary transmission line 40 processed in parallel (YES in step 151), that means that the test cells from all of the remote stations in the communication system were able to be received normally from the primary transmission line 50 or the secondary transmission line 40, wherefore it is judged that there are no failures affecting any of the remote stations in the communication system (step 146), and the failure detection processing based on the test cell transmission is terminated.

However, in the case where it is judged in step 143 that the test cell was not able to be normally received via the secondary transmission line (NO in step 143) and it is judged in step 149 that the test cell was not able to be normally received via the primary transmission line (NO in step 149), it is judged that a failure has occurred between the nth remote station and the mth remote station (step 152).

Now, when the central station 10 has detected, by the processing described in the foregoing, that a failure has occurred in one of the remote stations 20-1 to 20-5 or in a transmission line, transmission line turn-back is effected by the remote stations neighboring the remote station 20-1 to 20-5 or transmission line where the failure has occurred, and the system is thus reconfigured, under the control of that central station 10.

A specific example of such system reconstruction by the central station 10 after the occurrence of a failure is now described with reference to Fig. 16.

In Fig. 16, when the fact that a failure has occurred either in a transmission line connecting the (n – 1)th remote station 20-(n – 1) with the nth remote station 20-n or in that nth remote station 20-n is detected by the central station 10, the central station 10 transmits cells containing failure occurrence particulars addressed to the remote stations neighboring the nth remote station 20-n in the sector where the failure occurred, that is, to the (n-1)th remote station 20-(n-1) on the upstream side and the (n+1)th remote station 20-(n+1) on the downstream side, via the other remote stations.

Looking at the cell transmission method at this time, for the (n - 1)th remote station 20-(n - 1), the cells are transmitted over the primary transmission line 40 in the direction of 1st remote station → 2nd remote station → ···, while for the (n + 1)th remote station 20-(n + 1), on the other hand, the cells are transmitted over the secondary transmission line 50 in the opposite direction as that for the (n - 1)th remote station 12 noted above.

For a cell addressed to the (n - 1)th remote station 20-(n - 1), the remote stations upstream therefrom perform switching control so that that a cell not addressed to them is simply passed downstream. In response thereto, when the (n - 1)th remote station 20-(n - 1) receives that cell, it recognizes that that cell is addressed to itself, and thereby performs switching control on its own

ATM switch so that the primary transmission line 40 used in receiving that cell is connected to the secondary transmission line 50. As a result, the turn-back transmission line 81 is formed between the (n - 1)th remote station 20-(n - 1) and the central station 11.

After the switching control described above has been effected, a cell transmitted in response to the cell noted above that was received from the (n - 1)th remote station 20-(n - 1) is transmitted back to the central station 10 over that turn-back transmission line 81.

For a cell addressed to the (n + 1)th remote station 20-(n + 1), the remote stations upstream therefrom (downstream on the primary transmission line 50) perform switching control so that that cell, which is not addressed to them, is merely passed downstream. In response thereto, the (n + 1)th remote station 20-(n + 1), upon receiving that cell, recognizes that that cell is addressed to itself, and thereby switch-controls its own switch so that the secondary transmission line 50 used in receiving that cell is connected to the primary transmission line 40. As a result, a turn-back transmission line 82 is formed between the (n + 1)th remote station 20-(n + 1) and the central station 10. After the switching control described above has been effected, a cell transmitted in response to the cell noted above that was received from the (n + 1)th remote station 20-(n + 1) is transmitted back to the central station 10 over that turn-back transmission line 82.

In this manner, with this system, the central station 10 judges the status of failure occurrence in the remote stations 12 and proximate transmission lines based on information transmitted back from the remote stations in response to test cells. When a failure occurs, the central station 10 transmits cells carrying command information (i.e. information containing the failure occurrence particulars noted earlier) addressed to the affected remote stations,

and the controllers (CPUs) in the remote stations addressed activate switch controls corresponding to those cells received, forming a turn-back transmission line 81 or 82. Thereby the system can be reconfigured, and communications can be maintained over that turn-back transmission line 81 or 82.

In reconfiguring the system after the occurrence of a failure in this example, as described in the foregoing, turn-back transmission lines 81 and 82 are formed at the remote stations neighboring the nth remote station 20-n in the sector where the failure occurred. Needless to say, however, the formation of such turn-back transmission lines is not limited to neighboring remote stations in the sector where the failure occurred. For example, when a failure occurs in the nth remote station 20-n, while forming a turn-back transmission line 81 at the (n - 1)th remote station 20-(n - 1) neighboring that nth remote station 20-n, a turn-back transmission line may be formed at the (n + 2)th remote station 12 once removed from that nth remote station 20-n, or something like that done, so that turn-back control can be effected at any remote station according to the dissemination of the cells carrying the command information.

This system also has functions for restoring the system to the initial configuration including the nth remote station 20-n after completing the processing for restoring the nth remote station 20-n or the proximate transmission line where the failure occurred as described in the foregoing.

For the control method in that case, there is, for example, the method of issuing cells having information particulars for releasing the loop back, from the central station 10, addressed to the neighboring remote stations 20-(n - 1) and 20-(n + 1), after the central station 10 has learned of the restoration of the nth remote station 20-n.

Furthermore, when the configuration provides each remote station with a switch for passing cells not addressed to itself downstream, and, independently, with a switch for looping back and returning cells that are addressed to itself, a method is conceivable wherein, even after the occurrence of a failure, test cell transmissions are continued from the central station 10 to the nth remote station through the (n - 1)th remote station 20-(n - 1), the receipt of the return of a test cell from that nth remote station 20-n associated with the restoration from the failure in the nth remote station is waited for, and a cell having information particulars for releasing the loop back is issued, addressed to the neighboring remote stations 20-(n - 1) and 20-(n + 1).

Next, an other embodiment relating to the monitoring of failure occurrence in this system, and to the reconstruction of the system after a failure has occurred, is described with reference to Fig. 17. In this figure, 10a is the transmission point on the primary transmission line 40 of the central station 10 and the reception point on the secondary transmission line 50 thereof, while 10b is the reception point on the currently active transmission line 40 and the transmission point on the secondary transmission line 50.

In this embodiment, test cells are transferred from the point 10a of the central station 10 over the primary transmission line 40 to the remote stations 20. The remote stations 20 that receive the test cells successively transmit those test cells to the downstream remote stations 20 and transmit them back again to the point 10b of the central station 10. The central station 10 judges that there are no anomalies in the remote stations 20 or primary transmission line 40 by the fact that the test cells are safely transmitted back.

Similarly, test cells are transmitted from the point 10b of the central station 10 to the remote stations 20 over the secondary transmission line 50,

and, by monitoring the results of those transmit-backs, the remote stations 20 and secondary transmission line 50 can be monitored for failures.

In the failure monitoring described in the foregoing, in cases where a LOF/LOS is detected without a test cell being transmitted back to the central station 10, the central station 10 can judge that an abnormality has occurred either in a remote station 20 or in a proximate transmission line.

After making this judgment that an abnormality has occurred, the central station 10 uses the primary transmission line 40 and secondary transmission line 50 to transmit failure occurrence monitoring cells (test cells) simultaneously from point 10a and point 10b. The remote stations 20 that receive these test cells pass those received cells successively to the remote stations 20 further downstream, and thereby transmit those test cells back to the central station 10. At the central station 10, verification can be made of failure occurrence in the respective remote stations 20 and proximate transmission lines according to the status of test cell return, and operation is commenced at the point in time where the loop range broadens to maximum.

Thus, with this system, while continually transmitting test cells addressed to the remote stations 20 over the primary transmission line 40, monitoring information on the remote stations 20 and transmission lines is transmitted to the central station 10 from the remote stations 20 over the secondary transmission line 50, and, thereby, the monitoring of the remote stations 20 and transmission lines forming the loop network can be performed by the system itself (i.e. the central station 10).

As a result of this monitoring, when a test cell is not transmitted back from a remote station 20, a clear judgment can be made at the central station 10 that a failure has occurred either in the remote station 20 that failed to transmit back the test cell or in a transmission line on the nearer side thereof.

After such failure occurrence has been verified, the central station 10 can control the primary transmission line 40 and secondary transmission line 50 at the remote stations 20 neighboring the remote station 20 that failed to transmit back the test cell which the central station 10 itself issued so that they loop back.

By means of that control, when a failure occurs, the system can be reconfigured using portions thereof other than the site where the failure occurred, making this system extremely useful in applications in railroad management systems where, in the interest of safe operations, the system cannot be allowed to go down.

In particular, with the present invention, because ATM technology is used wherein the central station 10 or remote stations 20 are configured with ATM switches, multimedia data such as moving images, audio, or other data can be collected in an integrated manner. When applied to communication systems (cf. Fig. 1) used in communications networks connecting data originating entities and data processing centers in cases where the data generating entities or data receiving devices are arranged in looped configurations, it is possible to quickly collect and process other types of information. Thus extremely sophisticated control functions can be effected in a wide range of fields including sewer line control, airport control, and river control, in addition to the railroad management described earlier.

Fig. 18 is a system configuration diagram in another embodiment of a communication system configured using method and system for detecting failure of a ring network according to the present invention.

The communication system illustrated in Fig. 18 is configured so that, by having nodes 10 and 20-1 to 20-5 monitor the communication routes between those nodes and neighboring nodes, the time required for failure

detection when a failure occurs can be shortened, and a differentiation can be made as to whether the failure which occurred is a node controller failure or a failure at a site affecting a communication route.

More specifically, each node is given cell insertion and cell extraction functions, communication route monitoring cells are periodically transmitted and received between neighboring nodes, and communication route failures are detected when a communication route monitoring cell is not received from a neighboring node. Thus, by providing each node with the communication route control functions described above, in addition to simply effecting monitoring from the central station or node controller, it becomes possible to quickly detect not only transmission line failures but also internal node failures relating to the communication routes, and thus to further enhance system reliability.

In Fig. 18, the symbols 90-1, 90-2, 91-1, 91-2, 92-1, 92-2, 93-1, 93-2, 94-1, 94-2, 95-1, and 95-2 indicate communication route monitoring paths established in order to allow the nodes 10 and 20-1 to 20-5 to monitor the communication routes between those nodes and neighboring nodes.

These nodes 10 and 20-1 to 20-5 periodically transmit and receive communication route monitoring cells between themselves and neighboring nodes using these communication route monitoring path 90-1 to 95-2, thus monitoring the communication routes between those nodes and neighboring nodes.

Here, the VPI/VCI used in these communication route monitoring paths differs from the VPI/VCI used in terminal communication paths or node control paths. For example, VPI/VCI = 0/1022 might be assigned to the communication route monitoring path 91-1 and VPI/VCI = 0/1023 to the communication route monitoring path 91-2.

Fig. 19 is a diagram of how a node 20-n monitors the communication routes between the nodes 20-(n - 1) and 20-(n + 1) connected to both ends thereof using communication route monitoring cells.

In Fig. 19, first, the node 20-n, using its cell insertion function, outputs a communication route monitoring cell wherein VPI/VCI = 0/1022 to the transmission line 50-1 side. This communication route monitoring cell passes over the transmission line 50-1, is looped back at the node 20-(n - 1), and is output to the transmission line 40-1.

At the node 20-n, it can be detected that the communication route is normal on the neighboring node 20-(n - 1) side by receiving the communication route monitoring cell output to that transmission line 40-1.

Similarly, the node 20-n, using its cell insertion function, outputs a communication route monitoring cell wherein VPI/VCI = 0/1023 to the transmission line 40-2 side. This communication route monitoring cell passes over the transmission line 40-2, is looped back at the node 20-(n + 1), and is output to the transmission line 50-2.

At the node 20-n, it can be detected that the communication route is normal on the neighboring node 20-(n + 1) side by receiving the communication route monitoring cell output to that transmission line 50-2.

Fig. 20 is a diagram of how, when a failure occurs in a communication route of a node 20-n, that failure is detected by the nodes 20-(n - 1) and 20-(n + 1) connected to both ends thereof.

In Fig. 20, the node 20-(n - 1) transmits a communication route monitoring cell to the transmission line 40-1, but when a failure has occurred in the communication route of that node 20-n, that communication route monitoring cell is not returned over the transmission line 50-1. The node 20-

(n - 1) can thereby detect that a failure has occurred in the communication route of the node 20-n.

Similarly, the node 20-(n + 1) transmits a communication route monitoring cell to the transmission line 50-2, but when a failure has occurred in the communication route of that node 20-n, that communication route monitoring cell is not returned over the transmission line 40-2. The node 20-(n + 1) can thereby detect that a failure has occurred in the communication route of the node 20-n.

Here, the nodes 20-(n - 1) and 20-(n + 1) that detected that a failure has occurred in a communication route of the node 20-n notify the node controller of the occurrence of the failure in the communication route of the node 20-n, and can thereby support the restoration from the failure.

Furthermore, communication restoration can also be effected by having the nodes 20-(n - 1) and 20-(n + 1) that detected that a failure has occurred in the communication route of the node 20-n spontaneously execute loop-backs.

INDUSTRIAL APPLICABILITY

This invention is method and system for detecting failure of a ring network devised such that failure occurrence sites in a ring network wherein a plurality of nodes are loop-connected by transmission lines can be automatically identified, and such that communications can be rapidly restored when a failure occurs. Communications are conducted by doubly loop-connecting a plurality of nodes by a first transmission line and a second transmission line having mutually different directions, and establishing paths on those transmission lines, failure monitoring information is periodically transmitted to those transmission lines, failure occurrence sites are identified based on whether or not that failure monitoring information was able to be

looped back by the nodes and normally received, and communications are automatically restored based on the identification of that failed part. Thus the reliability of the communication functions can be sharply improved and system modifications can be dealt with flexibly.